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Recent excavations at Tilaurakot's southern Industrial mound: a preliminary report

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1. Introduction

Tilaurakot's southern industrial mound, known locally as Lohasariya, is a low mound located approximately 150 metres south of the ancient city. Measuring approximately 50 metres on its east to west axis and 30 metres on its north to south axis, metal-working residue is thickly scattered across its surface (Figure 1). The presence of this substantial area of metal-working beyond the city walls of Tilaurakot was first recorded by P.C. Mukherji during his survey in 1899. In a plan dating to the same year, Mukherji initially identified the mound as one of ancient Kapilavastu's cardinal stupas (Allen 2008: 191) but subsequently noted in his final report that "On the south of the southern ditch is a mound of earth, where is scattered a large amount of iron refuse, or something like it, which shows that there was a large workshop here in ancient days" (1901: 22). This early identification was not pursued by Debala Mitra of the Archaeological Survey of India, whose plans of the site did not extend past the moat on the southern edge of the city (1972). Characterised by an extremely high surface density of slag, a sondage was excavated into the mound in the 1970s by B.K. Rijal of the Department of Archaeology, Government of Nepal, although no detailed report was

published. Consequently, one of the primary aims of the 2012 excavation was to characterize and scientifically date this industrial activity and thus to articulate it with the cultural sequence of the ancient city, while the 2014 geophysical survey to define its spatial distribution.

2. Geophysical survey of the southern industrial mound

In order to better define and characterise the subsurface archaeological deposit, which would in turn facilitate research and inform management and conservation issues, particularly with regard to any future development, we undertook a geophysical survey between the southern rampart and around the southern industrial mound. The northern part of this 2.7 hectares area comprised open grazing with the broad low mound of the southern industrial mound, and its associated debris to the south. The southern, western and eastern edges of the mound were defined by small fields, typically paddy, mustard and dhal. It was not possible to collect survey data in some parts of the area due to some thicker stands of scrub and near ripe dhal crops. The survey area measured an area of 140 metres north to south and 180 metres east to west (Figure 2) and measurements of vertical geomagnetic field gradient were determined using a Bartington Instruments Grad601-2 dual fluxgate gradiometer. The sample interval was 0.25 metres and the traverse interval was one metre, thus providing 3,600 sample measurements per 30 metre grid unit. Anomalies on the northern edge of the survey reflect a slight bank along the southern edge of the partially silted moat south of the metalled road. Immediately south of this bank is a very broad band of smooth, almost featureless data, some 55 metres wide. It is possible that this band reflects a second or earlier moat, filled with silt. Two positive magnetic anomalies within the possible moat area correspond to the location of a cricket square, and may reflect material that has been deposited to provide a level surface.

To the south of the possible moat is a large concentration of intense magnetic anomalies, which reflects the mound of metal-working debris. Several larger dipolar magnetic anomalies were detected along the northern side of the mound. The orientation of some of these anomalies is such that they could reflect structures which were fired in situ; such features which might survive include the floors of smelting furnaces. However, these anomalies

could also reflect larger ferrous items. One possible furnace lies just north-east of an earlier excavation trench and others may lie to the north-west. Our geophysical survey has thus demonstrated the possibility of the presence of a second moat located beyond and to the south of Tilaurakot's known rampart and moat complex, whilst also suggesting further industrial activity around the southern industrial mound. The identification of potential furnaces correlates well to the identification of a possible furnace within Trench S and further demonstrates the industrial nature of activity in this area of Tilaurakot and also the distribution of archaeological remains beyond the walled urban core of the site.

3. Excavations at the southern industrial mound

A single cardinally-oriented trench, Trench S, was excavated on the mound in order to provide a chronometric sequence. Measuring four by three metres, it was sited immediately north-east of Rijal's old trench, which was approximately located in the centre of the low mound (Figure 3). The excavations utilised the context system and the phases of activity are described in reverse chronological order – from earliest to latest.

3.1 Phase 1

The first significant phase of cultural activity at the site appears to have involved the deliberate creation of a mound, thus raising of the area above the local level of inundation. The in situ natural, a mottled yellow and grey clay with kanker and manganese inclusions, was sealed at a depth of 2.15 metres below the surface by a clean fine grey sand context (29) containing both slag and Red Ware (RW) ceramic sherds. The interface between these would thus appear to represent an extant palaeosurface, while the fine sand appears to represent slow flowing water, likely relating to branches of the nearby Banganga River, thus demonstrating the need to raise the ground level above that of the surrounding flood plain. This grey sand was in turn overlain by a thin bar of olive brown sandy clay context (30), rich in slag, with occasional brickbat and charcoal flecking and several sherds of ceramics, including a single sherd of Cord Impressed Ware (CIW). This deposit was radiocarbon dated to between the early sixth and late fifth centuries BCE. More significantly, this grey sand and overlying bar were sealed by a thin crust of iron-panning, which is potentially indicative

of seasonal standing water in an iron rich environment. However, the iron-panning is almost certainly a later formation, most likely formed by water draining through iron-rich deposits of slag above, before pooling upon the impermeable surface of the in situ natural clay.

3.2 Phase 2

This was then followed another episode of deliberate mound creation, raising the area above the level of the plain and likely above the level of localised flood waters, as represented by the pale grey sand in Phase 1. This deliberate mound creation appears to have occurred in two distinct episodes. Firstly, the deposition of an initial 0.4 metre thick platform of redeposited natural with frequent cultural inclusions such as charcoal, slag, fragments of furnace lining and ceramics including sherds of RW, Black Slipped Ware (BSW) and CIW. Secondly, this was subsequently sealed by a thick, ranging from 0.35 to 0.60 metres, and similar layer of re-deposited natural. Again, this deposit of sandy clay loam included cultural inclusions, such as sherds of CIW and charcoal, in addition to fragments of slag and furnace lining. A radiocarbon sample from this secondary episode of mound creation was dated to between 373 and 199 BCE (95.4% confidence), representing perhaps an intensification in industrial activity. Notably the presence of artefacts associated with iron smelting – such as slag and furnace lining – suggest the presence of iron extraction prior to the creation of mound. The upper surface of this artificial mound sloped sharply upwards towards the north-east corner of the trench, as seen in Figure 4 on the south-facing section. In the centre of the trench, however, an oval shaped mound was formed through the deposition of two cultural tips, both consisting of silty clay loam, oriented approximately east to west and sloping up the west of the trench. This mound, measuring some 0.70 metres thick, was rich in cultural material, including charcoal, CIW and several fragments of RW oil lamps. The formation of this oval-shaped mound appears to mark the end of artificial mound creation at the site, creating a mound above the level of the surrounding plain and, hypothetically, above surrounding flood waters.

3.3 Phase 3

This mound creation appears to have been followed very quickly, without hiatus or interim deposition, by the construction of what has been tentatively identified as the entrance or opening of a furnace, context <014>. A charcoal sample from this context produced a radiocarbon date of between 198 and 105 BCE (68.2% confidence), reinforcing the suggestion that this industrial activity closely followed mound creation. Unfortunately, it would appear that the bulk of the furnace lies immediately west of the trench section, only extending slightly from the east-facing section into the trench. The visible portion of this furnace takes the form of two symmetrical 'arms' of highly-heated pale blue clay (as seen in Figures 5 and 6). These 'arms', measuring approximately 0.65 metres in length and 0.25 metres in breadth, were positioned approximately 1.00 metre apart, with the opening wider to the east and narrowing towards the east-facing section. Following the construction of this potential furnace to the west, several episodes of slag dumping appears to have occurred around the base of the oval-mound, suggesting that fairly intensive in situ iron smelting was occurring during this time. As can be seen in the south-facing section (Figure 4), the dumping appears to have occurred from the west; the area identified as the likely location of the furnace, with material sloping down from east to west within the trench.

3.4 Phase 4

These dumps of slag were then overlain by an arcing tip (see south-facing section Figure 4) of furnace lining context (012=016) that again appears to have been deposited from the west, overlaying the slope of the slag heap formed by the previous episodes of dumping during Phase 3. However, although context (012=016) was rich in furnace lining, the positioning and orientation of these fragments argues strongly against in situ collapse and likely represents collapse or demolition off site and the subsequent dumping of the material on top of the existing slag heap. This tip of furnace lining was then followed by a levelling episode, with a relatively clean deposit of sandy silt raising the level of the surrounding deposits to that of the mound and the furnace arms <014>. These contexts were then sealed beneath a 0.35 metre thick collapse spread of furnace lining and brickbat with frequent slag inclusions within a dark yellowish brown silty clay loam matrix, and covering the western extent of the trench. Again, this collapse does not appear to be in situ, given

the positioning and alignment of the furnace lining fragments. Instead, it once again appears to have been deposited from the west, the area identified as most likely to have been the site of in-situ industrial activity, as well as the location of Rijal's trench.

3.5 Phase 5

The final phase of activity at the site is marked by three extremely similar dumps of slag, initially sealing the furnace collapse and then sealing each subsequent of slag in turn. These contexts contained a quite extraordinary density of slag inclusions, in addition to moderate inclusions of charcoal, furnace lining and brickbat (Figure 7). Finally, in the north-west of the trench, bioturbation and site abandonment led to the deposition of a greyish brown silt topsoil, overlying the final slag dump. However, topsoil was absent from the majority of the trench with the final slag dump forming the surface deposit across the larger area of the area.

4. Metalworking Analysis

These excavations indicate that the southern mound functioned as a major extra-mural industrial locus from the fourth century BCE onwards, with the identification of later furnaces dating from second century BCE and clear evidence of in situ metal-working and the deposition of large quantities of slag. Indeed, the tips of furnace material suggest the periodic collapse or destruction of furnaces. A small amount of metal-working debris was sampled from the 2012 excavations at Trench S for further laboratory analysis at Durham University by Jennifer Jones. In total, 7.444 kilograms of industrial residues were examined from Trench S in order to characterise the residues and, where possible, identify the industrial processes from which they originated. The residues were examined visually or under X16 light microscopy, on freshly fractured surfaces with classifications based primarily on morphology, density, colour and vesicularity. Category criteria follow English Heritage Centre for Archaeology's Guidelines on *Archaeometallurgy* (Bayley *et al.* 2001). In addition, EDXRF (Energy Dispersive X-Ray Fluorescence) analysis, using an Oxford Analytical ED2000 facility and methods designed to detect a range of major, minor and trace elements, was carried out on five selected sub-samples, to assist with characterisation and identification.

4.1 Iron-working Residues

Almost all the material examined comes from iron-working and is residue from either smelting or smithing activity. Smelting is the first stage of the iron-working process, involving extraction of the metal from the ore in a furnace, where the ore is heated to separate the iron silicate slag from the iron bloom. Smelting slag is mainly an iron silicate, incorporating impurities from the iron ore, the furnace lining and from the fuel used. Smelting slag was usually periodically allowed to flow out of the furnace, tapped through a hole or tuyere in the furnace wall so that smelting could continue longer without a build-up of slag hindering the process. Smithing slag is the residue from working the iron bloom which results from smelting. This is a spongy mass of metallic iron still containing a high percentage of trapped slag and this slag must be hammered out of the bloom by smithing before objects can be forged from the metal. The iron bloom is kept at a high temperature during smithing to facilitate slag expulsion and the expelled slag consolidates into drips and pools around the smithing hearth. Accumulations of smithing slag would be periodically broken up and disposed.

It is not entirely clear from the visual examination, or EDXRF analysis, whether the Tilaurakot residues result from smelting or smithing activity. Much of the material is similar in appearance and lacks the usual (European) appearance of tap slag, whereby the upper surface is characteristically flowed and 'ropey'. The Tilaurakot interiors are dark and vesicular but possibly not quite dense enough for smelting residue. However, the extrapolated size and shape of the blocks of originally molten residue is more suggestive of smelting than smithing activity. All the fragments analysed have been broken up from larger blocks, many in antiquity, as evidenced by the formation of corrosion products on the broken edges. Traces of a curved edge survive on some pieces, suggests that the residues were originally circular. A very rough estimate of between 24 and 26 centimetres has been calculated for the diameter of the original blocks, using the curvature of the surviving edge fragments.

Many fragments have relatively smooth surfaces on one or both of the faces (Figure 8) and these are dark and/or red and heat-affected in colour and often show the fine creasing associated with skin formation on a rapidly-cooling liquid (Figure 9). The blocks are conjectured to have been roughly circular, flattish in the centre (between 1 and 4 centimetres thick) with thicker and rougher raised edges. The fairly smooth faces of the fragments suggest that the molten residues were expelled onto prepared surfaces rather than directly onto rough ground. Only two fragments, context (021) Y021 and context (012) SF42, have very small traces of clay attached, possibly originating from furnace or hearth. No fragments of burnt fuel were observed. Several pieces of residue have folded while in a plastic state, leaving an air pocket between the folds (Figure 10). This indicates that the residue was expelled rapidly and in sufficient quantity to cause it to pool and fold before it lost its plasticity on cooling. The production of such a relatively large volume of residue in one session suggests either that this is smelting residue or the existence of a large scale smithing operation.

Two samples, Context (002) SF7 and 023 <Y027>, were selected for EDXRF analysis and the sub-samples crushed and pelletised to ensure homogeneity. The analysis detected mainly iron (44% and 51%) and silica (35% and 34%), along with a range of earth elements such as magnesium, aluminium and calcium. Constituents of both smithing and smelting residues can be very variable, which is reflected in analysis results. This variability results from the source and quality of the ore used and from the efficiency of the iron working process. Figures obtained from the small number of analyses carried out for this assessment are not sufficient for a definitive identification of the material examined.

4.2 Other Residues

Only 0.053 kilograms of non-ferrous residue were identified. One sample, Context (003) <Y004>, comprised a number of tiny spheres of iron-rich material along with a single sphere of corroded copper alloy. Examination of the interior of one of the iron spheres found it to be lamellar and homogenous with no indication of vitrification or vesicularity as would be expected if it were associated with metal-working. It was concluded that the iron-rich

spheres are of natural origin. The single copper alloy sphere was not broken open but EDXRF analysis of its surface detected some copper and tin, with traces of zinc and lead. It is probable that this represents an accidentally melted fragment of copper alloy. Evidence of corroded copper alloy was observed in three other samples from contexts (015) <Y028>, (022) <Y023> and (030) <Y26>. The matrix of all three is very dark in colour, very light weight and vesicular, and has the appearance of fuel ash slag (FAS). FAS is formed when the non-organic components of fuels react with silicates present in earth, stone or ceramic. It can form at temperatures achievable in a domestic fire or conflagration but its presence is not necessarily indicative of industrial activity. The samples from context (022) <Y023> and context (030) <Y26> have visible traces of green corroded copper alloy on the surface and very small red and green copper-rich areas were observed inside <Y023> when it was broken open (Figure 11). A sample was crushed, pelletised and analysed using EDXRF. A very small quantity of copper (<1%) was detected but the analysis was dominated by silica, iron and other earth elements characteristic of FAS. The weight and density of these samples is much too low to be residue from copper alloy-working and, again, it is likely that the copper alloy was accidentally melted in a fire.

4.3 Summary

The vast majority of residues undoubtedly derive from iron-working processes. However, this assessment could not determine whether this process was large scale smithing or smelting. Whilst the original size and shape of the residues, together with the evidence of rapid cooling of relatively large volumes of molten material, suggests smelting, the relatively low density of the material and (possibly) the EDXRF analyses are perhaps indicative of smithing.

5. Discussion and Conclusion

The results of the geophysical survey, excavation and laboratory analysis suggest that the mound to south of the walled city of Tilaurakot was a major zone of production. Although it is not yet fully certain that the metal-working at Lohasariya relates to smelting, there is no doubt that manufacturing of metalwork, specifically iron, was undertaken here on an

industrial scale. Our excavations have demonstrated that cultural activity in the area of the industrial mound potentially began in the beginning of the sixth or fifth century BCE. Evidence of metal-working is apparent in the artefactual record relating to the creation of an artificial mound, continued through the use of redeposited natural, between 373 and 199 BCE with further industrial activity, represented by a furnace, following shortly after at a date of between 198 and 105 BCE.

One of the major objectives of the excavations at Trench S was to better understand the articulation between this important industrial site and the Early Historic city itself. Whilst evidence of metal-working, as indicated by residues and crucible fragments, has been found throughout the core walled urban form, the density of slag within is nowhere comparable with that of the southern industrial mound (Coningham *et al.* in press). Indeed, Trench S yielded almost 8 tonnes of slag, the vast majority relating to the potential decommissioning of the area in Phase 5. As it is likely that slag would not be transported far from the location of its initial production and neither would debris from furnaces, we may confirm that the southern mound hosted a major industrial complex from the fourth century BCE onwards. Furthermore, the geophysical survey also suggests the potential for other furnaces located around the southern industrial mound, strengthening this assertion for a concentration of industrial activity, although some caution is required as these geophysical anomalies have yet to be characterised or dated through archaeological excavation.

Compared to small scale smithing and metal-working within the confines of the fortifications of the city, such a vast industrial scale of manufacture and production would be extremely polluting and we would suggest that this major industrial activity was purposely located outside the city. Indeed, the location of a major industrial complex beyond the city's walls and moats suggests that there was active civic planning in terms of the zoning of core activities (Coningham and Young 2015: 218). Whilst small scale craft-working was practiced inside the city, large scale works were located outside the boundaries of the main urban core, away from the major concentration of habitation. Future research should address how this industrial activity was linked to the surrounding hinterland, as well as international and regional trade and exchange networks, especially with the evidence for

goods and materials from elsewhere in South Asia currently being discovered and processed in current excavations across the site.

Our research at Trench S, and on the southern industrial mound more generally, has also highlighted the dangers to the preservation of Tilaurakot's subsurface industrial heritage. Our identification of a possible second moat, running parallel to the southern rampart and the presence of potential furnaces associated with the southern industrial mound, informed a recent Heritage Impact Assessment at Tilaurakot which considered the building of a Bus Park on the site (Coningham *et al.* 2014: 84). Subsequently, these plans were rejected due to the negative impact on subsurface archaeological material identified by our research (Weise 2014). This demonstrates the very pressing need to conduct archaeological assessments prior to any proposed developmental activity within heritage sites in Nepal as well as the importance of linking archaeological sites with their broader and immediate hinterlands.

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7. Figures

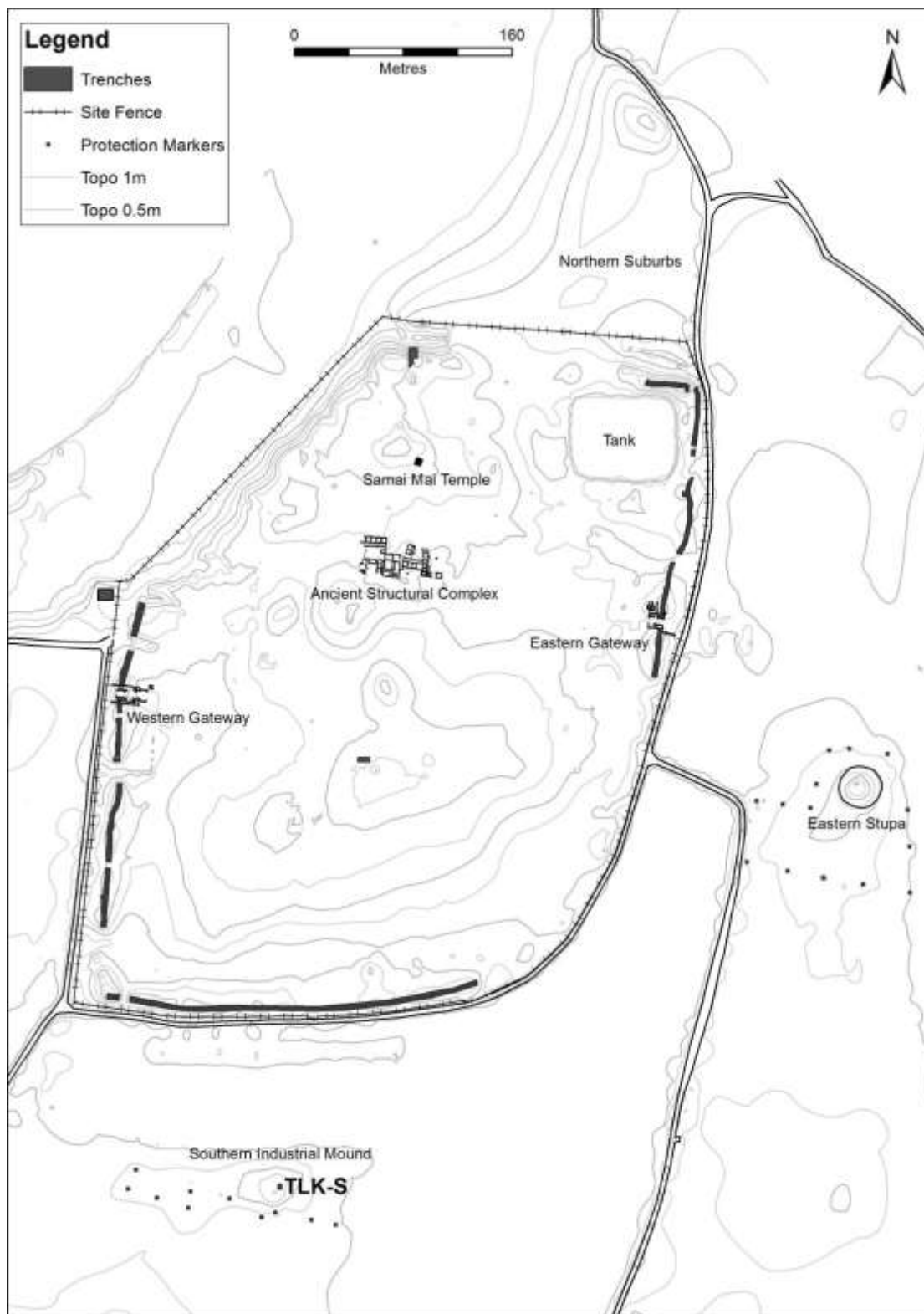


Figure 1: Location of Trench S on the southern industrial mound to the south of the fortified core of the city of Tilaurakot.

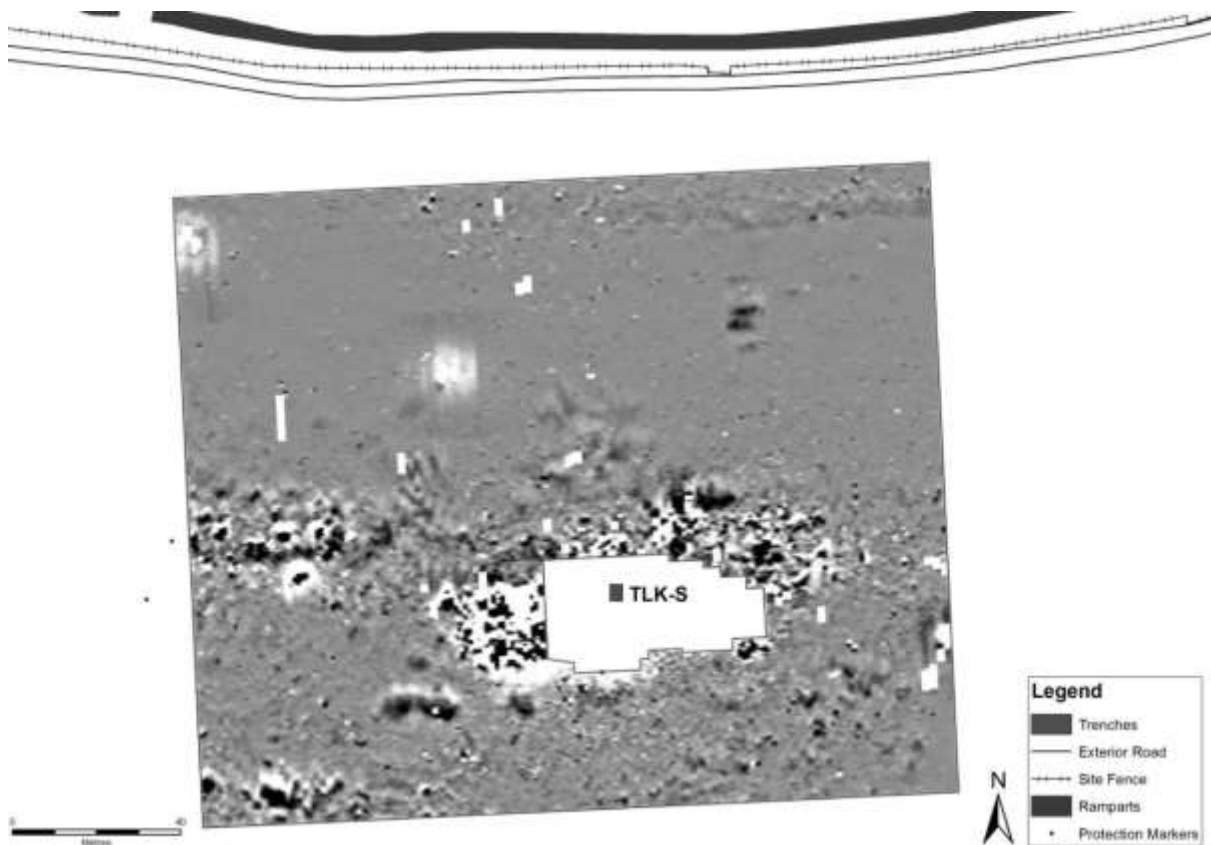


Figure 2: Geophysical survey results around the southern industrial mound.

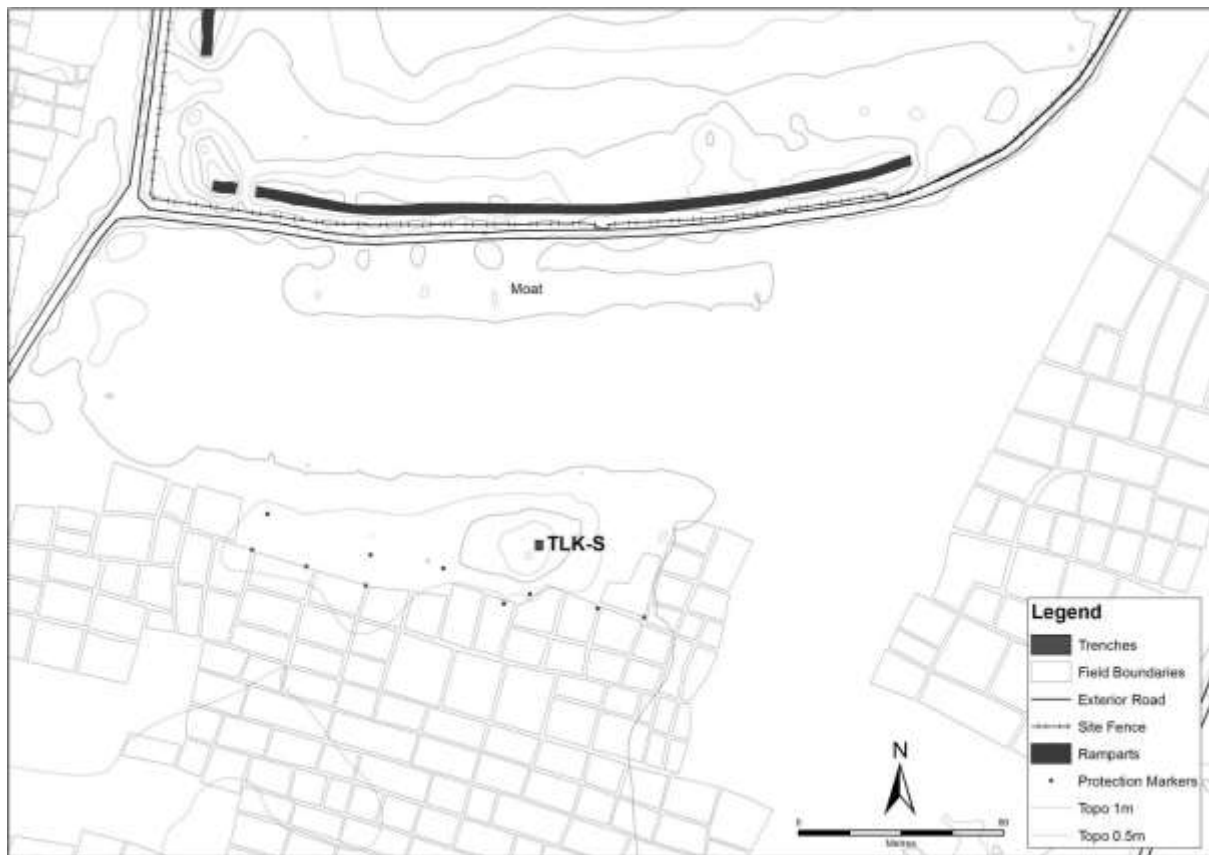


Figure 3: Detail of the location of trench S in relation to surrounding modern field systems and the southern moat and rampart of Tilaarakot.

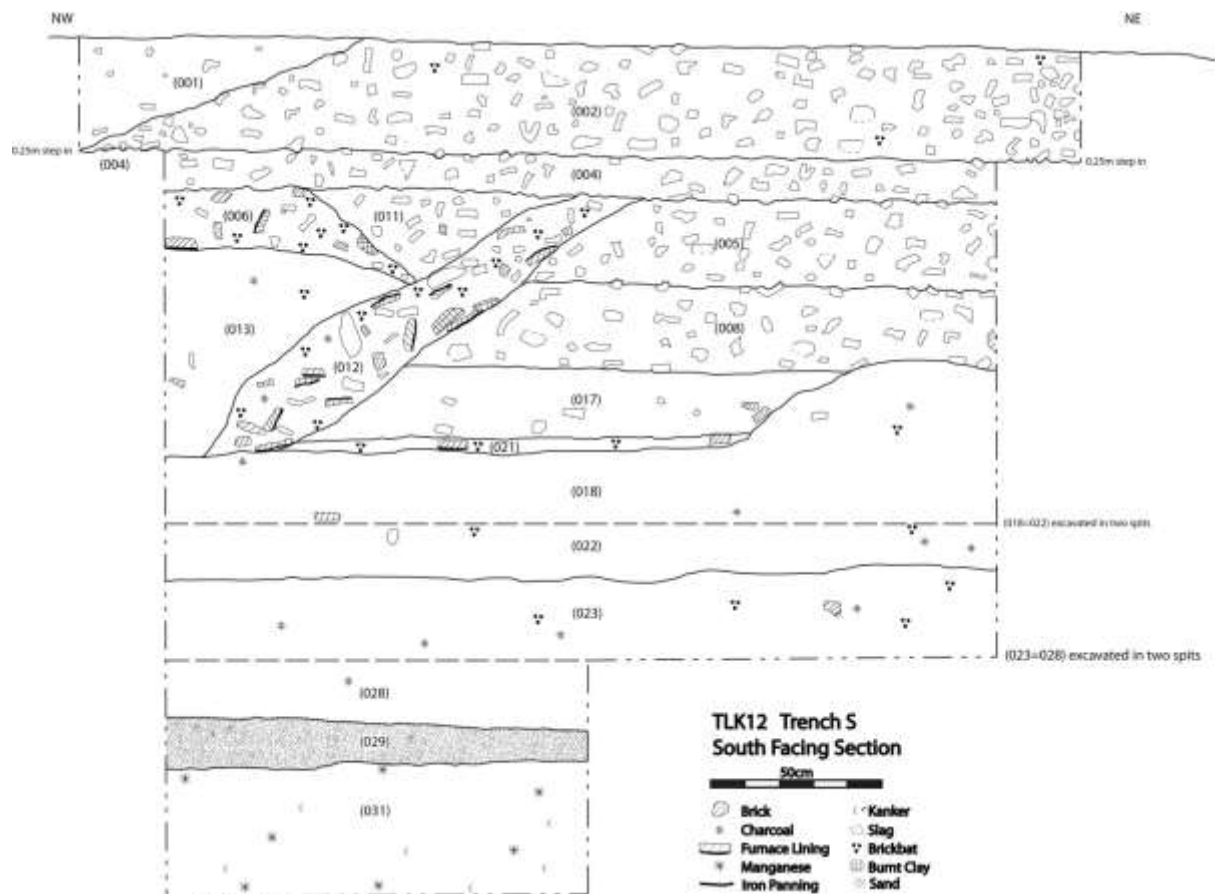


Figure 4: Trench S, South facing section

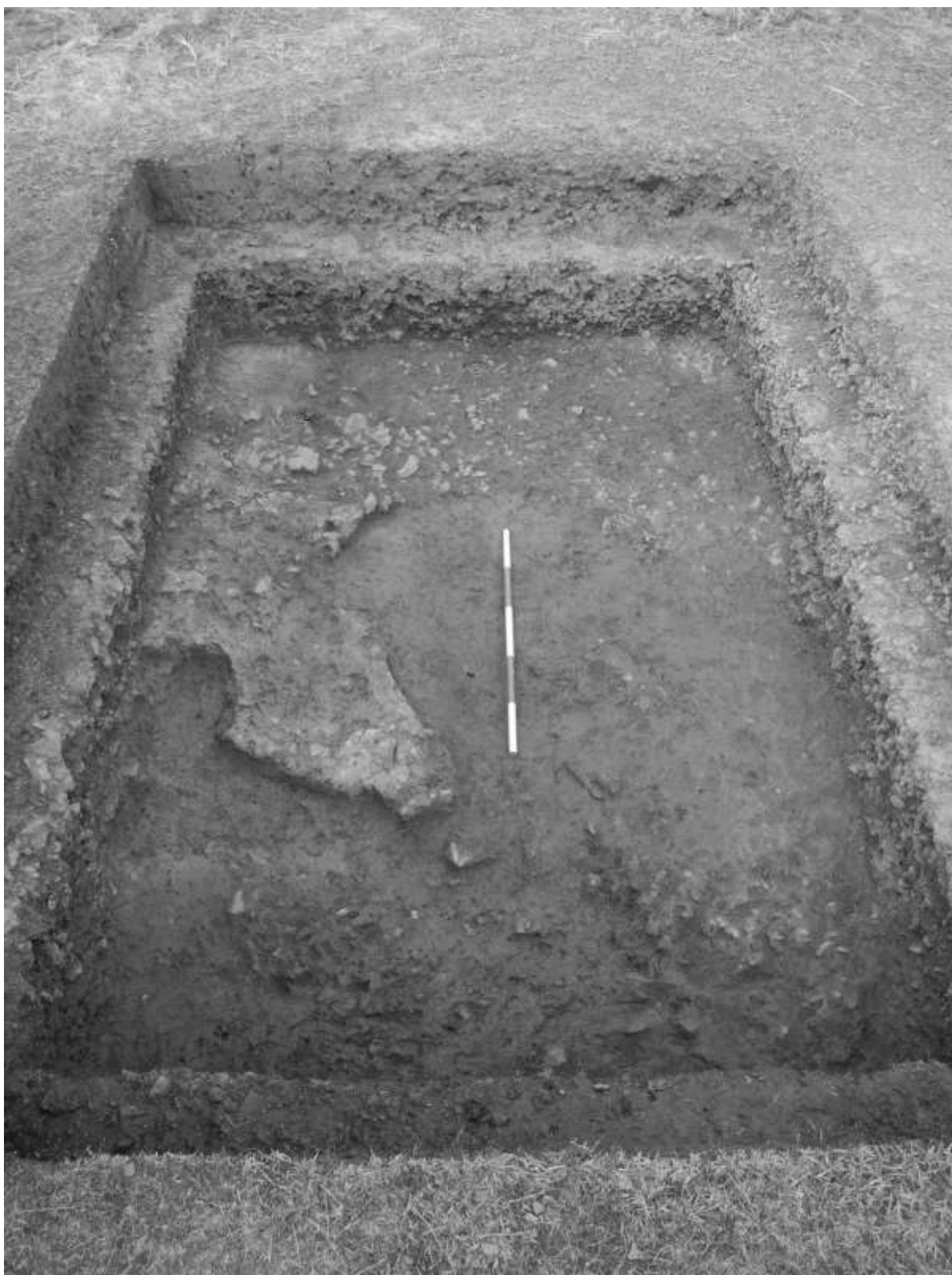
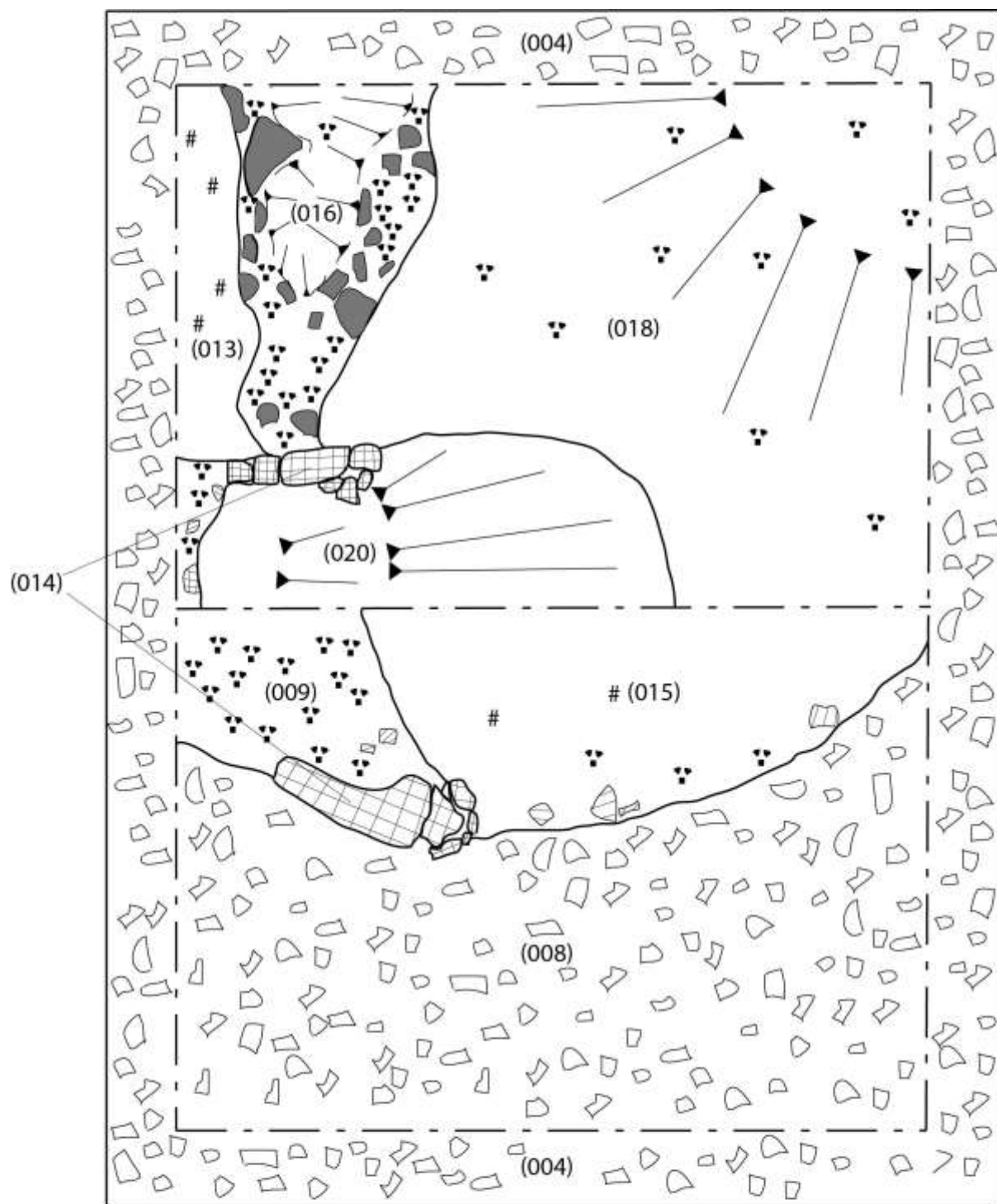


Figure 5: Furnace in Trench S below slag dumps.



Tilaurakot 2012
Trench S
Plan of furnace collapse and
tip (014), (106) & (020)

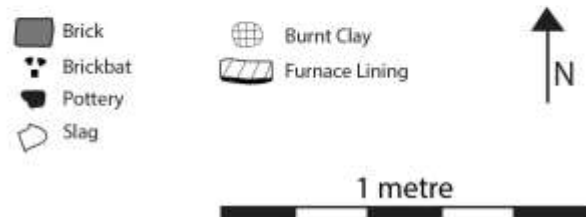


Figure 6: Plan illustrating half section of furnace collapse and tip.

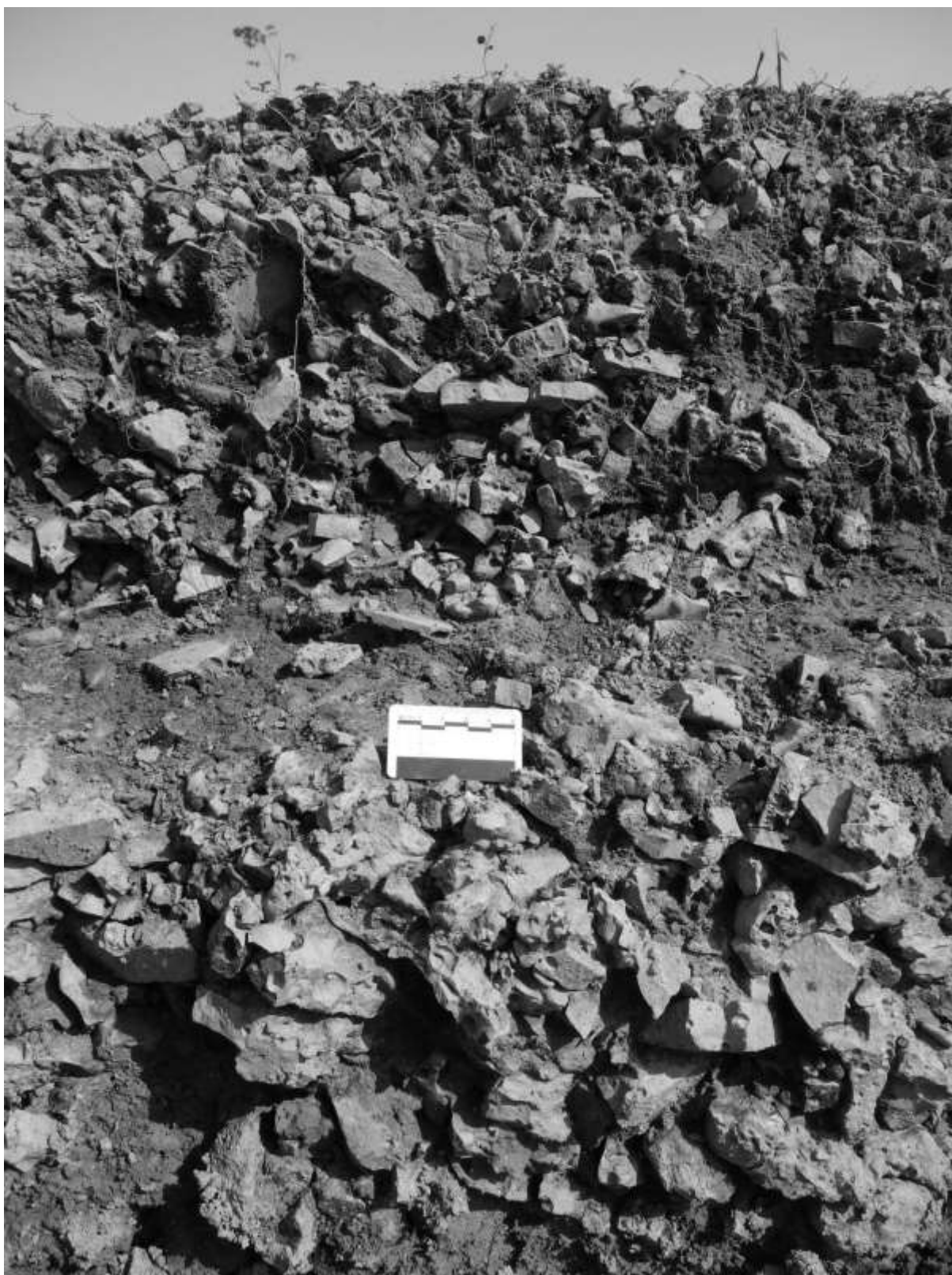


Figure 7: Slag rich contexts 004 and 005 in west facing section.



Figure 8: Large broken fragment of iron slag showing smooth dark surface and part of the original curved edge.



Figure 9: Small fragment of iron slag showing fine surface creasing.

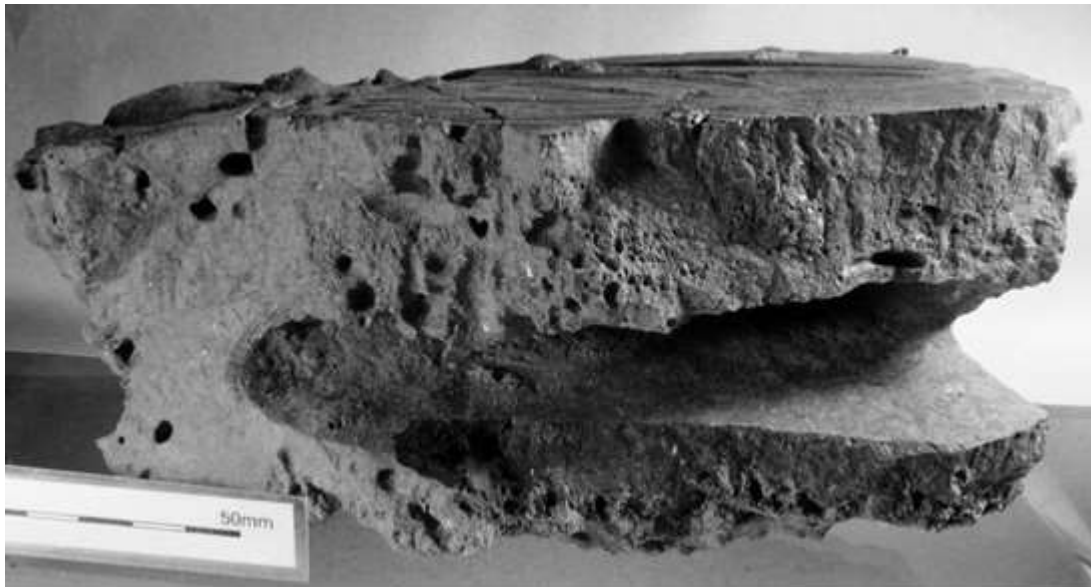


Figure 10: Large piece of folded iron slag residue



Figure 11: Interior of <Y023> from context (022), showing minute spots of red and green copper alloy in the dark, vesicular FAS matrix.